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A Model of Housing Attributes: Theory and Evidence

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A Model of Housing Attributes: Theory and Evidence

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Abstract

This paper presents empirical results designed to test the spatial predictions of a theoretical model of housing attributes. Housing is viewed as a commodity with two produced attributes, floor and yard space; the theory implies that the spatial behavior of these attributes over distance to the employment center must conform to certain restrictions. The empirical results validate the model while showing that a multiple attribute approach to analysis of housing consumption and production is empirically more robust than the familiar "housing service" approach.

A Model of Housing Attributes: Theory and Evidence*

by

Jan K. Brueckner and Peter F. Colwell

1. Introduction

The last decade has witnessed rapid growth of an empirical literature designed to estimate and interpret hedonic housing price functions. Although early studies (see Kain and Quigley [5] and Grether and Mieszkowski [4]) lacked an explicit theoretical foundation, recent papers (see Linneman [6] and Witte et. al. [9]) reflect the impact of Rosen's 'implicit-market' analysis of hedonic price determination [8], which has clarified the interpretation of hedonic prices and showed the need for additional estimation to identify consumer tastes.

In spite of this empirical focus on the pricing of housing attributes, the literature lacked until recently a detailed Rosen-type housing model capable of portraying the provision of housing attributes with the degree of realism and rigor found in the "housing service" models widely used in urban spatial analysis. This gap in the literature has been filled by a model of Brueckner [3] in which consumers value two produced housing attributes, floor space and yard space, and a third (non-produced) attribute, accessibility to an employment center. In the model, housing developers react to a consumer bid-rent function, which relates dwelling rent to the levels of the attributes, in choosing profit-maximizing characteristics of housing complexes. Among the theoretical questions addressed by the model, those concerning the spatial behavior of floor and yard space per dwelling are of special interest: will dwelling size (floor space) increase with distance to the central business

district (CBD), as in the standard model? Will yards be larger farther from the CBD? As will be seen in the next section of the paper, where the theory is sketched, restrictions on the spatial behavior of the attributes are relatively weak, admitting a number of possibilities. With the spatial implications of the model spelled out, the paper's main results are presented in the third section, where the theory is confronted with real-world evidence using data from a sample of houses in the Chicago metropolitan area. Regression results show that the actual spatial behavior of floor and yard space in the sample, while consistent with the predictions of the analysis, is surprisingly at variance with the conclusions of the standard housing service model. The empirical section further explores the properties of the sample by presenting results from regressions relating house value to the levels of attributes. A final section of the paper contains conclusions.

2. The Model

The first assumption of the model is that consumers have identical tastes which are represented by the strictly quasi-concave utility function $v(c,q,y)$, where c is consumption of a numeraire non-housing good, q is consumption of floor space, and y is consumption of yard space. An additional assumption is that all urban residents have the same income m (this requirement will be relaxed later). With uniform incomes, all urban residents must reach the same utility level in equilibrium, which means that all urban consumption bundles must satisfy $v(c,q,y) = u$, where u is the uniform utility level. Since $v_1 > 0$, this relationship may be inverted to yield $c = z(q,y,u)$, which gives the amount of c required to generate utility u for given consumption levels of floor

and yard space. Since the above relationship is simply the equation of an indifference surface, it follows that z is a strictly convex function of q and y. Now after paying commuting cost and house rent R, the consumer must be able to purchase just enough c to reach utility level u. This means that rent R for a dwelling located x miles from the CBD providing q and y worth of floor and yard space must satisfy

$$m - t(x) - R = z(q,y,u), \tag{1}$$

where t is the commuting cost function. Rearrangement yields the consumer bid-rent function

$$R(q,y,\theta) \equiv m - t(x) - z(q,y,u), \tag{2}$$

where θ represents the vector (x,u,m). Eq. (2) gives the rent consistent with utility level u as a function of the housing attributes and income. It follows from (2) and the definition of z that $R_1 = v_2/v_1 > 0$, $R_2 = v_3/v_1 > 0$, and $R_3 = -t' < 0$; holding u and m fixed, rent is increasing in q and y and decreasing in x. Recalling that z is strictly convex in q and y, it also follows that R is a strictly concave function of these variables.

Housing developers choose the characteristics of their output to maximize profit with the knowledge that consumer rental payments must satisfy (2). Note that although the utility level u, which determines the level of the bid-rent function, is endogenous in a closed city setting, utility enters parametrically in the developer's optimization problem. As in the standard model (see Wheaton [11]), the utility level achieved in equilibrium under the present model is determined by

market-clearing conditions stating that the urban housing stock is just adequate to house the urban population. Brueckner [3] presents a detailed discussion of this market equilibrium; for the purposes of the present paper utility will be assumed to equal its equilibrium value.[1]

The first technological assumption is that the amount of floor space in a developer's housing complex is given by $H(N,\ell_1)$, where N is the capital input and ℓ_1 is the amount of land physically covered by the capital (referred to subsequently as "building land"). The function H, which is assumed to be concave and exhibit constant returns to scale, is analogous to the production function for housing services (which are typically viewed as the services derived from floor space) in the standard model (see Muth [7]). Since q equals floor space per dwelling, it follows that the number of dwellings contained in the housing complex equals $H(N,\ell_1)/q$. Now the consumption of yard space by each resident will depend on the total amount of land ℓ_2 devoted to yard space in the complex. Although a communal yard in a housing complex is in fact a public good (apartment building residents jointly consume the amenities afforded by the building's grounds), a fundamental assumption is that yard space exhibits the congestion properties of a private good in that yard consumption per resident equals per capita yard area, or ℓ_2 divided by the number of residents in the complex. This assumption yields $y = \ell_2 q/H(N,\ell_1)$. It is shown in Brueckner [3] that if yard space is a pure public good (so that $y = \ell_2$) or behaves like a public good with congestion properties intermediate between those of pure public and private goods, then the developer's objective function exhibits increasing returns and his optimization problem has no solution.[2]

Under the above assumptions, the developer's profit equals

$$\frac{H(N,\ell_1)}{q} R(q,y,\theta) - r\left(\ell_1 + y\frac{H(N,\ell_1)}{q}\right) - nN \tag{3}$$

where n is the (exogenous) rental price of capital and r is the (endogenous) land rent per acre. Note that HR/q in (3) is revenue for the housing complex and that yH/q equals total yard land ℓ_2. Since H exhibits constant returns, (3) may be written

$$\ell_1\left[\frac{h(S)}{q}\left(R(q,y,\theta) - yr\right) - nS - r\right], \tag{4}$$

where $S \equiv N/\ell_1$ is structural density and $h(S) \equiv H(S,1) = H(N,\ell_1)/\ell_1$ gives floor space per acre of building land, with $h'(S) \equiv H_1(S,1)$. The quantity in brackets in (4), denoted π, is profit per acre of building land.

For any given ℓ_1, developers choose S, q, and y to maximize π, and competition bids up land rent r until the maximized value of π equals zero. Developers are then indifferent to the value of ℓ_1; the size of housing complexes is indeterminate. This fact is simply a consequence of the constant returns property of the optimization problem, which is in turn due to the private good congestion feature of yard space and the assumption of constant returns in floor space production. The first-order conditions $\partial\pi/\partial S = \partial\pi/\partial q = \partial\pi/\partial y = 0$ translate into the following requirements (see [3]):

$$\frac{h'(S)}{q}\left(R(q,y,\theta) - yr\right) = n \tag{5}$$

$$\frac{v_2(z(q,y,u),q,y)}{v_1(\quad -\quad)} = \frac{n}{h'(S)} \tag{6}$$

$$\frac{v_3(z(q,y,u),q,y)}{v_1(\quad -\quad)} = r \tag{7}$$

The first condition says that the marginal revenue per acre of building land from increasing S (LHS) should equal the marginal cost of doing so, n. The last condition says that the marginal rate of substitution between yard space and the numeraire should equal the marginal cost of yard land, r. The second condition says that the MRS between floor space and the numeraire should equal the marginal cost of floor space (which equals $n/H_1(N,\ell_1) = n/H_1(N/\ell_1,1) \equiv n/h'(S)$, noting the zero-degree homogeneity of H_1). The fourth condition $\pi = 0$ completes the four-equation system which determines S, q, y, and r. It can be shown that the resulting solution is equivalent to a tangency in (R,q,y) space between the consumer bid-rent surface and an iso-profit surface of the developer, as in the Rosen [8] framework (see [3]).

Recalling that the size of housing complexes is indeterminate, it follows that the model applies equally well to large apartment building complexes (where the number of dwellings $H(N,\ell_1)/q$ is large) and single-family houses (for which $H(N,\ell_1)/q \equiv \ell_1 h(S)/q = 1$). The optimal values of S, q, and y do not depend on whether capital is concentrated in large structures or partitioned among single-family houses.[3] For the purposes of the empirical work, however, the subsequent analytical results regarding the spatial behavior of S, q, and y will be taken as applying to single-family houses, even though the results are also appropriate for larger complexes.

By performing standard comparative static calculations using the system (5) - (7) together with the zero-profit condition, the effect of an increase in distance x (an element of θ in (5)) on the choice variables S, q, and y can be determined. The following central result emerges:

> Theorem (Brueckner [3]): While $\partial S/\partial x < 0$ holds for all x, the only constraint on the spatial behavior of floor and yard space is that both inequalities $\partial q/\partial x \leq 0$ and $\partial y/\partial x \leq 0$ cannot be satisfied.

The Theorem says that, as in the standard model, structural density is a monotonically decreasing function of distance to the CBD (houses have fewer storeys at greater distances). However, the only restriction on the behavior of floor and yard space is that both attributes cannot be (locally) non-increasing functions of x; at least one of these attributes must increase (locally) as distance to the CBD increases. Note that neither q or y need be a monotonic function of x; irregular spatial contours are admissible. When q and y are (non-constant) monotonic functions of x, however, the Theorem says that three possibilities are admissible: both q and y increase with x; q increases while y decreases with x; q decreases while y increases with x (note that dwelling size need not increase with distance as in the standard model). The proof of the Theorem depends crucially on the strict concavity of the bid-rent surface at each x. Although a fully satisfactory intuitive explanation is not apparent, it turns out that simultaneous satisfaction of $\partial q/\partial x \leq 0$ and $\partial y/\partial x \leq 0$ would violate the strict concavity of R.

Solution of the model for Cobb-Douglas utility and production functions gives more determinate results. Assuming $v(c,q,y) \equiv c^{\alpha}q^{\sigma}y^{\varepsilon}$ and $H(N,\ell_1) \equiv N^{\beta}\ell_1^{1-\beta}$, which gives $h(S) \equiv S^{\beta}$, considerable algebraic manipulation yields the following solutions for q and y:

$$q = \Lambda(m-t(x))^{\frac{\beta\varepsilon-(1-\beta)\alpha}{(1-\beta)\sigma+\varepsilon}}$$

$$y = \Omega(m-t(x))^{-\frac{\alpha+\beta\sigma}{(1-\beta)\sigma+\varepsilon}}, \tag{8}$$

where Λ and Ω are expressions which depend on u and n. Since all parameters are positive and $\beta < 1$, it follows from (8) that $\partial y/\partial x > 0$ and

$$\frac{\partial q}{\partial x} \gtrless 0 \text{ as } \beta \lessgtr \frac{\alpha}{\alpha+\varepsilon} \quad . \tag{9}$$

With Cobb-Douglas functions, yard space per house is monotonically increasing in x while floor space per house may be a monotonically increasing, decreasing, or constant function of x depending on the relationship between production and utility function parameters.

In the next section of the paper, regression results relating q, y, and a proxy for S to distance are presented for a sample of houses in the Chicago metropolitan area. The specification of these regression equations involves several issues that have not been discussed so far. First, although the model is static in nature, ignoring the time dimension of the urban economy, recognition of age differences

among dwellings is necessary in any empirical investigation. As a result, the analysis must be modified slightly to incorporate the element of time. Suppose first that dwellings are infinitely durable, so that once constructed they are never demolished (the static model implicitly assumes perfectly malleability of structures). Suppose in addition that the developer has static expectations, so that he believes that the income, utility, and commuting cost levels which underlie the bid-rent function (2) will remain constant forever. Under these assumptions, the expected present value of revenue for a house is $R(q,y,\theta)/i$, where i is the discount rate. Interpreting r and n in (4) as the purchase prices (instead of rental prices) of land and capital and substituting R/i for R, (4) then gives the expected present value of profit for the developer. Since the first-order conditions for the modified optimization problem are given by (5) - (7) with r and n replaced by ir and in (which now represent the implicit rental prices of land and capital), the solution is identical to the static case.

Since the exogenous quantities (income, the price of capital, and commuting cost) which underlie the developer's modified optimization problem will change over time, as will the endogenous utility level, it is clear that for a given x, the characteristics of a house will depend on its construction date. Although the Theorem can be used to predict differences in S, q, and y among houses constructed in different locations at the same date, it should be clear that the Theorem is invalid for predicting differences in the attributes of houses built in different locations at <u>different</u> dates. Ideally, the regression equations relating housing attributes to distance should control for

the values of the variables m, n, and u, as well as the general level of commuting costs, at the time a given house was constructed. Since the data requirements for such a specification are obviously impractical, the regression equations reflect a simpler approach in which the age of the house is included as a right-hand variable. This specification should adequately control for the effect of construction date differences on the levels of the attributes.

The fact that incomes are not uniform across space, as assumed in the development of the model, requires additional steps. For a given construction date, it is clear that spatial variation in income will mask the pure effect of distance on the housing attributes (the dependence of q and y on m can be seen in (8)[4]). Given this fact, an ideal procedure would be to control in the attribute regressions for spatial variation in construction-date incomes. For simplicity, a proxy for the current income of the house's occupant was included instead as a right-hand variable (the proxy is equal to the 1970 median income level for the census tract containing the house). While this approach is not strictly correct under the model, it is likely to yield a reasonably good approximation to the correct specification.

3. Empirical Results

a. Data

The sample data is drawn from 120 observations of single-family house sales in the north Chicago area. In addition to observations within the Chicago city limits, the sample includes houses in the communities of Morton Grove, Skokie, and Lincolnwood, which border Chicago on the north. The sample was drawn from 1979 MLS sales for which the required property characteristics were available.

The housing attributes of floor and yard space were computed from only slightly less than complete information. Floor space is taken to be the sum of the areas of rooms reported in the MLS data. This includes living room, family room, dining room, kitchen, and bedrooms, but excludes bathrooms and closets.[5] Yard space is computed by subtracting floor space on the ground floor of the house from lot area. By ignoring the potential presence of front porches and garages, this procedure will overstate yard area for some observations (in effect, the procedure counts porch and garage areas as yard space).

A proxy was used to represent structural density since no direct measure of capital was available (recall that structural density is the ratio of capital in the structure to the land area under it). The proxy, which equals the ratio of floor space on upper floors to floor space on the ground floor, assumes the value zero for a single-storey house but will be near two for a three-story house.

Access to employment is measured by straight-line distance from the house to the Chicago Loop (the intersection of State and Madison Streets). Distance is measured in thousands of block units, with distances in the sample ranging from 1.8 to 12.1 thousand block units (the mean is 8.7 thousand units). The spatial dispersion of the sample observations should allow a reliable test of the spatial predictions of the theory.

The selling price data used in the house value regressions in section 3c are the prices recorded by the MLS. A primary source of error in this type of variable is difficult to avoid. The error results from special financial arrangements (e.g., seller paid points, land contracts,

mortgage assumptions, etc.) that give rise to premia built into the selling price. Because of the great difficulty in obtaining full information on the financing of the sales, this paper, like all its predecessors, ignores the problem of financial premia.

b. Housing Attribute Regressions

The regression results reported in this section are designed to uncover the partial effects of distance to the CBD on the levels of the housing attributes. The estimated effects may then be compared to the predictions of the theory, which are contained in the Theorem of Section 2. The dependent variables in the regressions are y, q, and S while the independent variables are distance to the CBD (x), median tract income (m), and age of structure (denoted a). Several functional forms were estimated by OLS for each of the dependent variables; the results for linear, quadratic-in-distance, and log-linear forms are reported.[6] The quadratic form was estimated to determine whether the monotonic attribute-distance relationship implied by the linear and log-linear forms is justified.

The regression results are reported in Table 1. In each cell of the Table, the estimated coefficient based on the total sample of 120 observations is reported above the estimated coefficient based on the sub-sample of 63 sales from Chicago (t-ratios are in parentheses below the coefficients). All statistical tests referred to in the text are one-tailed tests at the 95% level of confidence.

Yard Space

Validation of the theory requires simultaneous consideration of the spatial behavior of floor and yard space per house. As stated

above, both floor and yard space cannot decrease (or remain constant) locally as distance increases without violating the theory. Although yard space by itself might exhibit any type of spatial behavior without contradicting the general theory, recall that the Cobb-Douglas model solution calls for yard space to increase with x.

In the linear regression (shown in the first line of Table 1), yard space is indeed an increasing function of distance for both the total sample and the Chicago sub-sample, confirming the Cobb-Douglas predictions. Yard space also increases with age and with median tract income, indicating that old houses in high income areas have large yards. While the positive effect of income on yard space might have been predicted by the model,[7] the result that old houses have large yards indicates that the parameters of the developer's optimization problem have changed over time in the sample in a way that makes smaller yards optimal. Note that all the coefficients in the linear equation are significantly different from zero and that the R^2 is fairly good.

In order to test for a non-monotonic yard space-distance relationship (recall that such a relationship is admissible under the model), a quadratic-in-distance regression was computed, with the results presented in the second line of Table 2. Although no distance coefficients are significant in the quadratic specification, the properties of the estimated parabolas for both the entire sample and the Chicago sub-sample were derived nevertheless. For the entire sample, the minimum point of the (upward-opening) parabola lies roughly at a distance measure of two, indicating that the parabolic relationship is monotonically increasing over most of the sample distance range. For the restricted sample, the

maximum point of the (downward-opening) parabola lies far beyond the range of the sample (at $x \approx 80$), again indicating a monotonic relationship in the sample range. Thus, the quadratic regressions offer no indication of a non-monotonic relationship between yard space and distance.

The log-linear regression shows yard space again to be an increasing function of distance (see the third line of Table 1). The closeness to unity of the distance elasticities for the total sample and the Chicago sub-sample suggests that the relationship between yard space and distance is close to proportional. As in the linear regression, age and income exhibit positive coefficients (the income elasticity, however, is not significantly positive for the sub-sample), and the R^2 is acceptable.

Floor Space

As long as yard space per house is an increasing function of distance, neither the general theory nor the Cobb-Douglas solution indicates whether floor space per house will increase, decrease, or remain constant with distance. As noted previously, however, the standard urban model requires housing services per dwelling (and hence floor space under the usual interpretation) to increase with distance. The spatial behavior of floor space in the sample surprisingly contradicts the standard model's predictions without being inconsistent with the present theory. This can be seen first in the fourth line of Table 2, where the distance coefficient in the linear regression is significantly negative for the entire sample and negative but insignificant for the Chicago sub-sample. Similar results emerge under the log-linear specification in the sixth line of the Table: the distance coefficients

are negative for both samples, although the coefficient for the entire sample is now insignificant. Since constant or decreasing floor space per dwelling is inconsistent with the standard model but consistent with both the general and Cobb-Douglas versions of the model developed in this paper, the evidence from the sample strongly indicates the superiority of an approach to urban spatial analysis which incorporates multiple housing attributes. It would, however, be premature to argue at this time for rejection of the standard model; reestimation using other samples is needed before a definitive verdict can be drawn.

As in the case of yard space, the distance coefficients in the quadratic floor space regressions are insignificant, with the point estimates failing to clearly indicate the presence of a non-monotonic relationship. For the entire sample, the maximum of the (downward-opening) parabola occurs at an x value between one and two, so that the implied relationship is monotonically decreasing over the entire sample. The (downward-opening) parabola for the restricted sample, however, reaches a maximum for x near five, so that the implied relationship is non-monotonic within the sample. The lack of significance of the coefficients, however, means that this conclusion cannot be taken seriously.

The income and age coefficients for the three regressions show that floor space is not surprisingly an increasing function of income (all coefficients are significant) and similarly increases with dwelling age. Note, however, that for each specification, the positive age coefficient is insignificant in the regression based on the entire sample. Thus, even though yards are larger in older houses, the evidence for a similar relationship in the case of floor space is mixed. Finally,

note that the R^2's for the floor space regressions are considerably smaller than for the yard space equations.

Structural Density

Like the standard model, the present theory requires that structural density decreases monotonically with distance. Two of the functional forms were used to test this proposition for the given sample (the log-linear function was not estimated because the proxy equals zero for single-storey houses). In accord with the theory, structural density indeed declines with distance; the coefficients of x are significant and negative for both the total sample and the sub-sample in the linear regression (see line 7 of Table 1). The coefficients of income and age are positive and significant for both samples, indicating that old houses in high income areas have high structural densities. While the quadratic functions exhibit by-now-familiar insignificant coefficients, the (upward-opening) parabolas for both samples are minimized beyond the relevant distance ranges of the data, providing no evidence of a non-monotonic relationship.

The main conclusions of this section can be summarized succinctly. The evidence shows that yard space per house in the sample is an increasing function of distance to the CBD, that floor space per house is a decreasing (or perhaps constant) function of distance, and that structural density is a decreasing function of distance. While all these conclusions are consistent with the general model and its Cobb-Douglas solution, the floor space results strongly contradict the spatial predictions of the housing service model.

c. House Value Regressions

This section reports regression results relating house value to the levels of q and y and distance to the CBD. These results are important for two reasons. First, the estimated coefficients show that consumers value floor and yard space, confirming the basic assumptions of the analysis. Second, the results show that distance to the Chicago Loop is a valid accessibility measure for the sample, discounting the possibility that the regression results in Section 3b reflect use of an improper accessibility variable.

The value of a house equals the present discounted value of net returns to the owner. Recall that in the basic model of Section 2, value P was equal to $R(q,y,\theta)/i$ under the assumption of static expectations. However, since the sample contains houses from different municipalities, modication of the basic model becomes necessary to capture the effect on house value of fiscal differences among cities. The modified value expression reflects the appearance of public good levels in the utility function and the fact that property taxes must be subtracted from rent to obtain the owner's net return. Value is given by $P = (R(q,y,\tilde{\theta}) - T)/i$, where T is the property tax payment and $\tilde{\theta} \equiv (\theta,g)$, with g representing the vector of public good levels. Since under ad valorem property taxation $T = \tau P$, where τ is the property tax rate, solving for P in the above value equation yields $P = R(q,y,\tilde{\theta})/(\tau+i)$. Note that the addition of a public sector to the model does not materially affect the developer's (modified) optimization problem. Although static expectations must be extended to cover public good levels and tax rates, and R in (4) must be replaced by $R(q,y,\tilde{\theta})/(\tau+i)$, the spatial

implications of the analysis are unchanged.[8] Rather than explicitly including public good levels and tax rates in the estimating equation, the house value regression reported below makes use of municipal dummy variables to control for fiscal differences. Separate dummies were used for the three non-Chicago municipalities in the sample (Morton Grove, Skokie, and Lincolnwood).

The value of a house is in reality related to its age, a fact which the analysis so far ignores. For purposes of estimating house value equations, it is assumed that age is a housing attribute which enters the utility function negatively along with q and y, reflecting the decline with age of the utility of floor space as a result of structural decay. Although this means that age will be an argument of the bid-rent function (exhibiting a negative partial derivative), the aging phenomenon can be ignored in formulating the developer's optimization problem (as was done above) provided that a suitable assumption is imposed. The necessary assumption is that in addition to possessing static expectations, the developer ignores the effect of aging on the time path of house rent in choosing the levels of the housing attributes. In essence, this means that the house value function which enters the modified optimization problem is based on the bid-rent function with its age argument set equal to zero. While this assumption is unrealistic, its imposition reflects a desire to avoid dynamic issues, which have been treated in detail elsewhere (see Brueckner [1]).

Before proceeding to the empirical results, it will be useful to indicate differences between the present approach to estimating house

value equations and the approach taken in the recent hedonic price literature. That literature (see [6], [9]) is based on the view that the observed relationship between house value and housing attributes is the locus of tangency points between a multitude of consumer bid-rent surfaces reflecting different incomes and tastes and an array of producer iso-profit surfaces. By computing the marginal attribute prices at points on the estimated hedonic price surface corresponding to the chosen attribute bundles of the various consumers in the market, consumer demands can be recovered in a second-step computation in which the chosen attribute levels are regressed on the appropriate marginal prices and consumer characteristics. Differences between the hedonic approach and the one followed below can be traced to the present study's assumption that consumers possess a common utility function. This means that all house value observations lie on bid-rent surfaces which are differentiated by underlying consumer income levels but otherwise have the same functional form. This means that as long as income is included in the house value equation, the estimated relationship reflects the form of the consumer bid-rent function and hence can be used to directly identify consumer tastes. Using an optimal data set, Wheaton [10] was able to derive precise estimates of utility function parameters by following a variant of the present approach. Data limitations, however, prevented the derivation of similarly reliable taste estimates in the present study.[9]

The form of the house value equation for which results are reported is

$$P = \gamma_0 + \gamma_1 m + \gamma_2 a + \gamma_3 \ln(\hat{x}) + \gamma_4 \ln(q) + \gamma_5 \ln(y) + \gamma_6 DSK + \gamma_7 DMG + \gamma_8 DLW, \quad (10)$$

where $\hat{x} \equiv x + 1$ and DSK, DMG, and DLW are the municipal dummies. This expression results from the following assumptions: $R(q,y,\tilde{\theta},a)/(\tau+i)$ approximated by $(R(q,y,\theta,a)/\psi) + \Sigma\delta_j D_j$, where the D_j represent the municipal dummies and ψ is a positive constant; the utility function is $v(c,q,y,a) \equiv c + \sigma\ln(q) + \varepsilon\ln(y) + \lambda a$ where $\sigma,\varepsilon > 0$ and $\lambda < 0$; utility is related to income according to the function $u = \phi + \nu m$, where $\nu > 0$ (this assumption follows Wheaton [10]); the commuting cost function is $t(x) \equiv \mu + \omega\ln(x+1)$, where $\mu,\omega > 0$ (the ln function is used to yield a concave $t(x)$ and $x + 1$ is used in place of x to guarantee non-negativity of commuting cost for small x).[10] The function (10) was chosen after estimation of a non-linear relationship based on a Cobb-Douglas utility function yielded disappointing results and other unsuccessful linear specifications were rejected.[11]

The first line of Table 2 gives the estimated OLS coefficients of (10). Note that the coefficients of ln(q), ln(y), and age are all significant with the correct signs, indicating that newer houses with large floor and yard areas are highly valued. The coefficient of income is significantly positive, a result which seems intuitively reasonable even though a negative sign would not be inconsistent with the theory (the income coefficient γ_1 in (10) equals $(1 - \nu)/\psi$, which may have either sign). An initial interpretation of the negativity of the suburban dummy variable coefficients (which are significant in the cases of Morton Grove and Skokie) is that the low suburban property tax rates are more than balanced by low public service levels, leading to low house values, other things equal. A different interpretation is suggested by the

performance of the distance variable, whose coefficient, while negative, is not significantly different from zero in apparent contradiction of the model. A possible explanation for this outcome is that the Morton Grove and Skokie dummies, which equal unity for the houses in the sample most distant from the CBD, capture much of the influence of accessibility on value. At the risk of ignoring the fiscal determinants of house value, the municipal dummies were deleted from the regression to evaluate this conjecture. As can be seen in the second line of Table 2, the distance coefficient becomes significantly negative in the modified regression, lending credence to the view that the dummies partly captured the effect of accessibility (note that the other estimated coefficients are qualitatively unchanged). Restricting the sample to houses within Chicago renders the distance coefficient insignificant once again without materially changing the other estimates ($\hat{x}$'s absolute t-ratio is, however, reasonably high). This outcome is understandable given that the range of x is markedly reduced by restricting the sample to Chicago observations, leading to less precise estimates. Note finally the reasonably high R^2's for the regressions, which indicate that the independent variables explain roughly half of the variation in house values.

Several conclusions may be drawn from the results in Table 2. First, the results show that floor and yard space are important determinants of house value, validating the fundamental premises of the model. Second, although the evidence is not entirely definitive, it appears that distance to the Chicago Loop is an adequate measure of accessibility to employment for houses in the sample. This is clearly

an important conclusion, since use of an improper accessibility variable would greatly reduce the significance of the attribute regression results of Section 3b.

4. Conclusion

It is hoped that this paper, together with the more detailed theoretical study ([3]) on which it is based, will help bridge the gap between the empirical hedonic price literature and the analytical literature based on housing service models. The theoretical section of the paper showed that a simple model which recognizes the existence of multiple housing attributes can be constructed in a fashion whose broad outlines are familiar from the housing service tradition. Although the model is appealing on purely theoretical grounds, the paper's empirical results suggest that reorientation toward a multiple attribute approach is warranted for reasons more substantive than pursuit of elegance or generality. This conclusion follows from the empirical finding that floor space per house is a non-increasing function of distance to the CBD in the sample, a result which conforms to present predictions while strongly contradicting the spatial implications of the housing service model. A researcher wedded to the notion of housing services might object that this indictment of the standard framework is based on too narrow an interpretation of the service concept (services, he might argue, are derived from other features in addition to floor space). Such a defense would, however, implicitly acknowledge the need for a model like the one developed in this paper.

TABLE 1

ATTRIBUTE REGRESSION RESULTS*

ND. VAR.	CONSTANT	x	x^2	ln(x)	a	ln(a)	m	ln(m)	R^2
	-36.7	5.09			.483		1.89		.425
	(-3.59)	(6.27)			(3.16)		(3.91)		
	-26.6	3.84			.552		1.67		.345
	(-2.11)	(3.44)			(3.71)		(2.53)		
	-16.8	-.315	.325		.494		1.96		.433
	(-.914)	(-.0744)	(1.30)		(3.25)		(4.04)		
	-27.8	4.23	-.0283		.550		1.66		.345
	(-1.36)	(.772)	(-.0729)		(3.64)		(2.49)		
	-1.24			1.10		.410		.514	.622
	(-2.57)			(9.53)		(5.59)		(3.27)	
	-1.20			1.06		.519		.396	.641
	(-1.67)			(6.34)		(5.41)		(1.62)	
	6.27	-.327			.0190		.498		.139
	(2.58)	(-1.69)			(.525)		(4.33)		
	4.19	-.447			.0874		.563		.155
	(1.09)	(-1.31)			(1.93)		(2.80)		
	4.76	.0837	-.0247		.0181		.492		.141
	(1.08)	(.0825)	(-.413)		(.497)		(4.24)		
	-.778	1.21	-.120		.0814		.546		.170
	(-.125)	(.728)	(-1.02)		(1.78)		(2.71)		
	.792			-.190		.0348		.700	.148
	(1.64)			(-1.64)		(.475)		(4.46)	
	.398			-.313		.215		.716	.156
	(.543)			(-1.84)		(2.20)		(2.88)	
	-.0411	-.0367			.00775		.0354		.111
	(-.167)	(-1.88)			(2.10)		(3.04)		
	-.0128	-.0631			.00705		.0475		.169
	(-.0376)	(-2.11)			(1.76)		(2.67)		
	.204	-.103	.00401		.00780		.0362		.114
	(.457)	(1.01)	(.660)		(2.14)		(3.08)		
	.262	-.155	.00663		.00738		.0484		.175
	(.476)	(-1.05)	(.636)		(1.82)		(2.70)		

lts for the total sample are given above results for the Chicago sub-sample. The t-ratios are rentheses. y is in units of 100 square feet. Average yard area for the total sample is $\bar{y}_t$ = whereas the average for the Chicago sub-sample is $\bar{y}_c$ = 41.2. q is in units of 100 square $\bar{q}_t$ = 11.9, and $\bar{q}_c$ = 11.4. s is the ratio of upper floor square feet to ground floor square $\bar{s}_t$ = .406, and $\bar{s}_c$ = .395. x is in thousands of block units. $\bar{x}_t$ = 8.67, and $\bar{x}_c$ = 7.46. s in years. $\bar{age}_t$ = 25.6, and $\bar{age}_c$ = 27.5. m is in thousands of dollars. $\bar{m}_t$ = 16.0, and 14.4.

TABLE 2

HOUSE VALUE REGRESSION RESULTS

IND. VAR. / DEP. VAR.	CONSTANT	m	a	$\ln(\hat{x})$	ln(q)	ln(y)	DSK	DMG	DLW	R^2
P	-26498. (-1.11)	1942.5 (3.00)	-593.59 (-3.29)	-6114.5 (-.488)	34025. (6.58)	9585.9 (1.88)	-15196. (-3.33)	-12639. (-2.58)	-5169.0 (-.752)	.529
P	16381. (.785)	1496.1 (2.62)	-628.60 (-3.40)	-25761. (-2.35)	32049. (6.01)	11702. (2.23)				.476
	-24966. (-.909)	2865.1 (3.22)	-688.56 (-2.98)	-19506. (-1.28)	29303. (4.29)	17112. (2.53)				.550

Footnotes

*We would like to thank Douglas Diamond, Jr. for comments and Dong Han for able research assistance. Any errors, of course, are ours.

[1]In an open city, of course, u will be exogenous.

[2]For a detailed discussion of congested public goods, see Brueckner [2].

[3]A different set of assumptions leading to a determinate complex size includes increasing returns in floor space production (due to, say, the economies from shared walls) and hyper-private congestability of yard space. The latter assumption means that holding per capita yard area fixed, yard space consumption falls with the number of yard users (see [3]).

[4]Note that since Λ and Ω in (8) depend on utility, which will be a function of income in equilibrium, the nature of the dependence of q and y on m is more complex than it first appears.

[5]While data were available on the number of bathrooms, information on their size (needed in computing floor space) and floor location (needed in computing yard space and structural density; see below) was not available.

[6]Results of the semi-log form yield no additional information. Since there is no rationale for transforming the dependent and independent variables differently, only the results from the simpler forms are reported.

[7]The comparative static calculations require an assumption regarding the change in utility which accompanies a change in income. Since such an assumption must be arbitrary, calculations are not presented. This conclusion also applies to the effect of income on q and S.

[8]Although intercommunity differences in fiscal variables will in principle affect the developer's choice of housing attributes, the municipal dummy variables were not included in the attribute regressions on the belief that such effects are likely to be unimportant.

[9]Wheaton's data included observations on individual household income and community cost, which allowed him to write his estimating equation in such a way that the parameters of Cobb-Douglas and CES utility functions could be estimated reliably (see footnote 11). This was not possible in the present study, as will be seen below.

[10]The coefficients in (10) are related to the underlying parameters as follows:

$\gamma_0 = -(\mu+\phi)/\psi \gtrless 0$; $\gamma_1 = (1-\nu)/\psi \gtrless 0$; $\gamma_2 = \lambda/\psi > 0$; $\gamma_3 = -\omega/\psi < 0$; $\gamma_4 = \sigma/\psi > 0$; $\gamma_5 = \varepsilon/\psi > 0$.

[11] The Cobb-Douglas utility function leads to a value function of the form

$$P = \gamma_1 m + \gamma_2 t(x) + \gamma_3 q^{\gamma_4} y^{\gamma_5} a^{\gamma_6} + \text{dummies},$$

which was difficult to estimate using non-linear least squares. Since he had data on individual household rental payments, income, and commuting cost, Wheaton [10] was able to estimate with OLS a function of the form

$$\ln(m-R-t(x)) = \delta_1 + \delta_2 \ln(q) + \delta_3 \ln(y) + \delta_4 \ln(a)$$

to recover Cobb-Douglas utility function parameters.

It should be noted that the specification (10) is actually inconsistent with the attribute regression results in Section 3b. The reason for this is that when $R_{21} \equiv \partial^2 R/\partial q \partial y = 0$ (as is the case for specification (10)), it follows that both q and y must be monotonically increasing functions of x, contrary to the findings of Section 3b (see [3]). Since attempts to estimate a value function with $R_{21} \neq 0$ gave poor results, (10) was estimated instead in spite of the fact that the functional form is not fully consistent with the attribute regressions.

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